Study of HγZ coupling using e+e- -> γ H at the ILC

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Outline

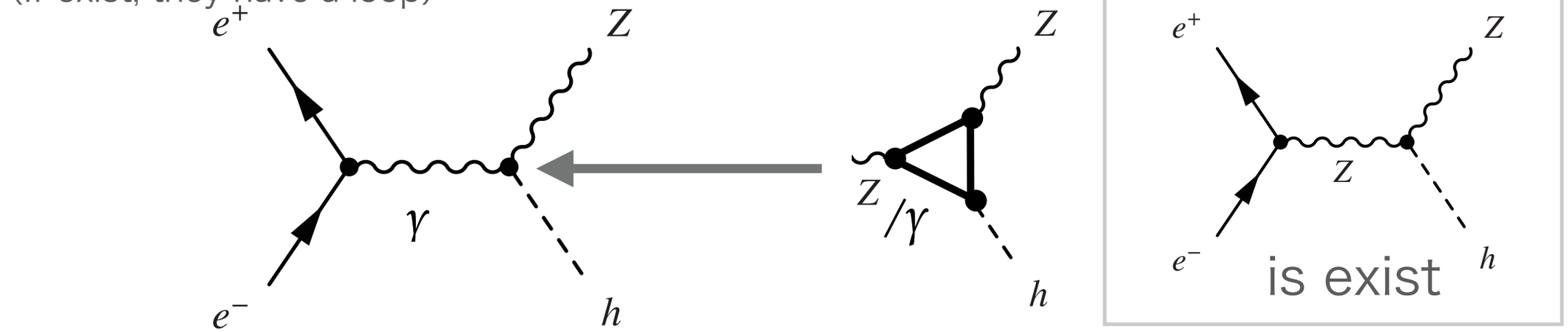
1. Motivation
2. Theoretical framework
3. Experimental method
4. Simulation framework
5. Event selection
7. Result
8. Next approach
9. Summery

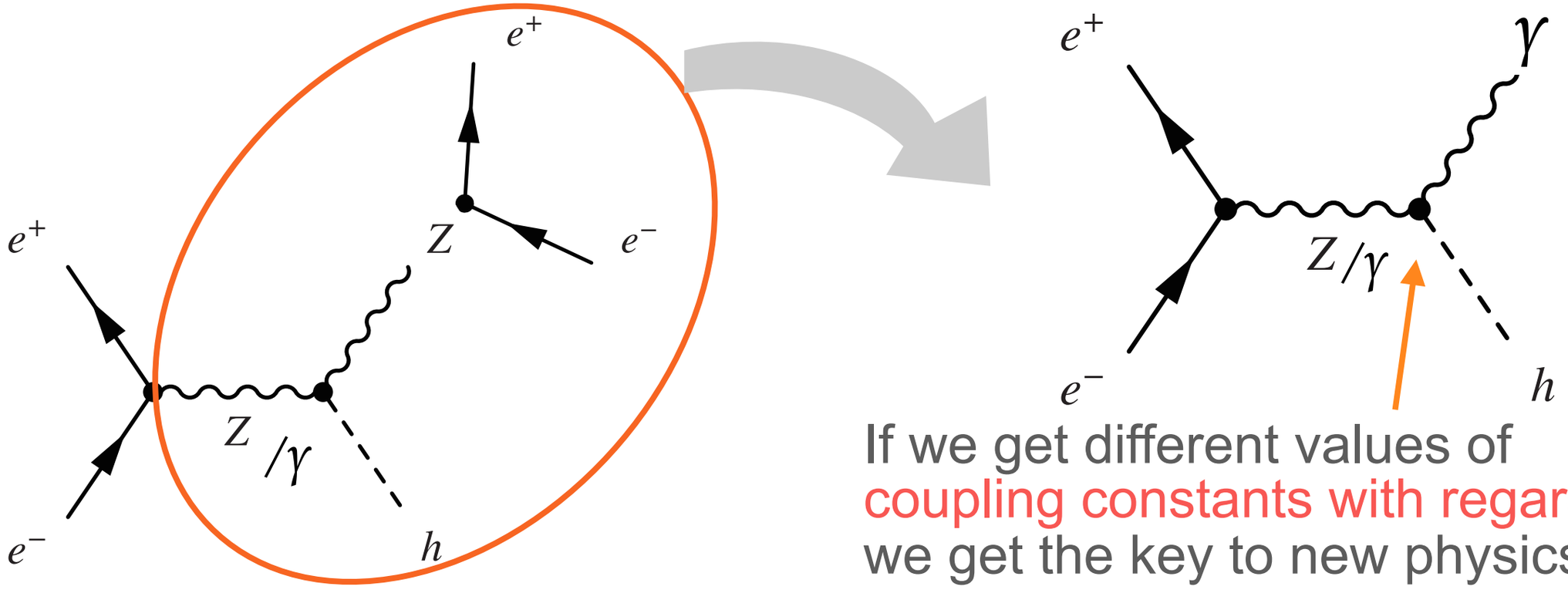
1.Motivation

Find new physics via H$\gamma\gamma$ and HγZ couplings

Below diagram is not exist in Tree level standard model

(If exist, they have a loop)





If we get different values of coupling constants with regard to SM, we get the key to new physics.

2. Theoretical framework

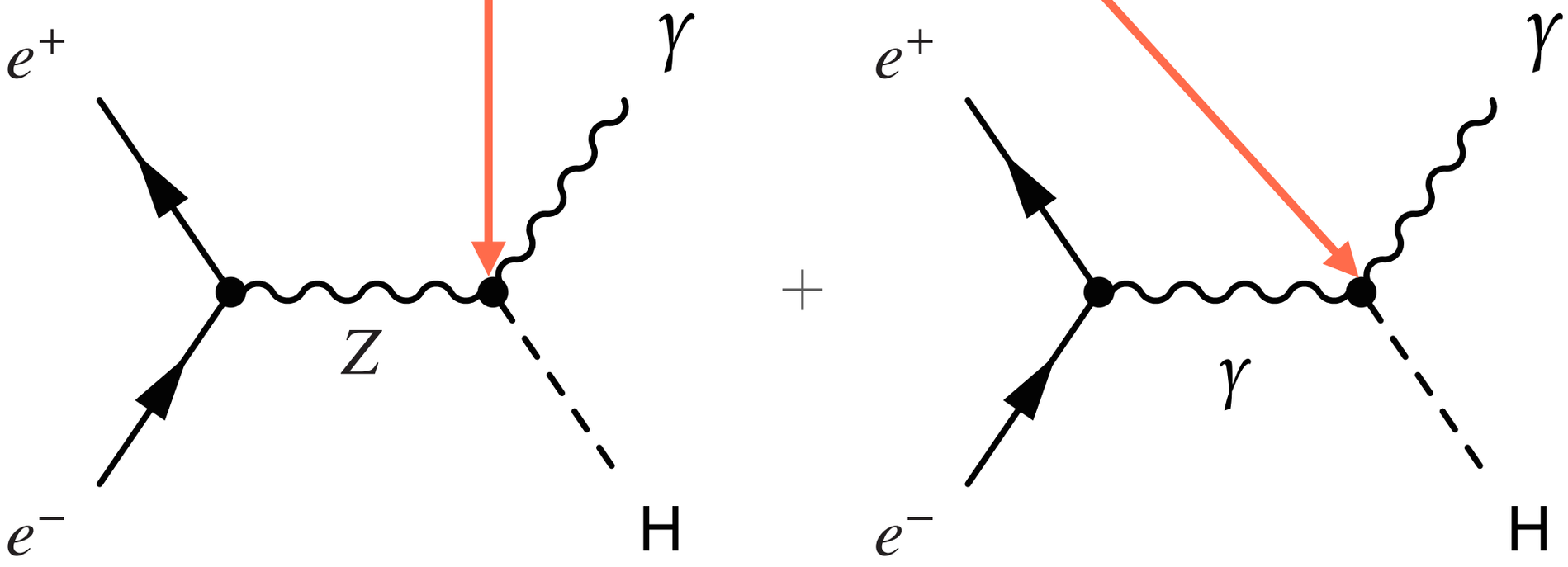
effective Lagrangian for e+e- —> γH

Coupling constant

$$L_{\gamma H} = \frac{c_{\gamma Z}}{4\Lambda} A_{\mu\nu} Z^{\mu\nu} H + \frac{c_{\gamma}}{4\Lambda} A_{\mu\nu} A^{\mu\nu} H$$

effective h γ Z coupling

effective h γ γ coupling



$c_{\gamma Z}$: effective coupling between Higgs and γZ (dimensionless)
c_{γ} : effective coupling between Higgs and γγ
Λ : effective new physics scale

2. Theoretical framework

partial decay widths of h->γγ and h->γZ: (calculation by EFT)

$$\Gamma_{\gamma\gamma} = \frac{M_H^3}{64\pi}(\frac{c_\gamma}{\Lambda})^2$$

(M_H = 125 GeV)

arXiv:1101.0593

$$\Gamma_{\gamma Z} = \frac{M_H^3}{128\pi}(\frac{c_{\gamma Z}}{\Lambda})^2(1 - \frac{M_Z^2}{M_H^2})^3$$

Standard model loop calculation

$\Gamma_{\gamma Z}$: 6.25 x 10^{-3} MeV —> $c_{\gamma Z} / \Lambda$ = 1.12 x 10^{-1} / TeV

$\Gamma_{\gamma\gamma}$: 9.27 x 10^{-3} MeV —> c_γ / Λ = 3.09 x 10^{-2} / TeV

By comparing with standard model loop calculation, we can extract the standard model values of $c_{\gamma Z} / \Lambda$ and c_γ / Λ.

3.Experimental Method

Coupling constant

$$L_{\gamma H} = \frac{c_{\gamma Z}}{4\Lambda} A_{\mu\nu} Z^{\mu\nu} H + \frac{c_{\gamma}}{4\Lambda} A_{\mu\nu} A^{\mu\nu} H$$

measure this 2 parameters

① Measure the cross sections of e+e- ->γh

for at least two different beam polarizations

So that c_{γ} and $c_{\gamma Z}$ can be determined separately

② Since $\frac{c_{\gamma}}{4\Lambda}$ can be constrained already by measurement of h→γγ branching ratio at LHC, we can extract other parameter by just measuring cross section for a single polarization.

3.Experimental Method (Continued)

γZ and γγ diagrams have the same momentum dependence in the cross section formula

→phase space integration can be factored out

→The cross section normalized to SM can be written as

$$\frac{\sigma_{e^+e^-\to h\gamma}}{\sigma_{SM}} = (a\bar{c}_{\gamma z} + b\bar{c}_{\gamma})^2$$

Coefficient a and b are calculated by physsim

Left handed beam polarizations

$$\frac{\sigma}{\sigma_{SM}} = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2$$

Right handed √s=250 GeV

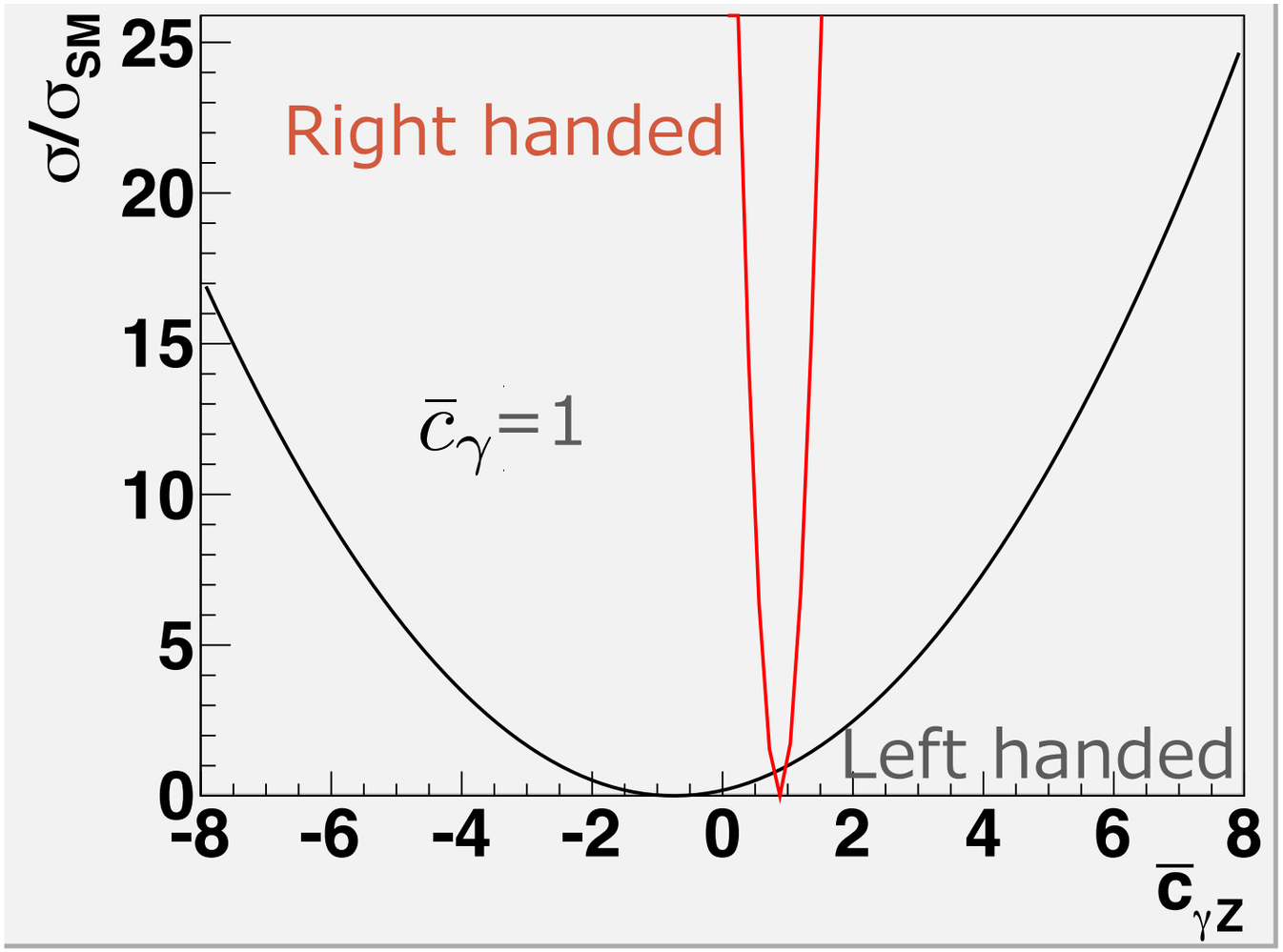
$$\frac{\sigma}{\sigma_{SM}} = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_{\gamma})^2$$

$$\bar{c}_{\gamma z} = \frac{c_{\gamma z}}{c_{\gamma z(SM)}}$$

$$\bar{c}_{\gamma} = \frac{c_{\gamma}}{c_{\gamma(SM)}}$$

3.Experimental Method (Continued)

The cross section relative to SM



Left handed

$$\frac{\sigma}{\sigma_{SM}} = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2$$

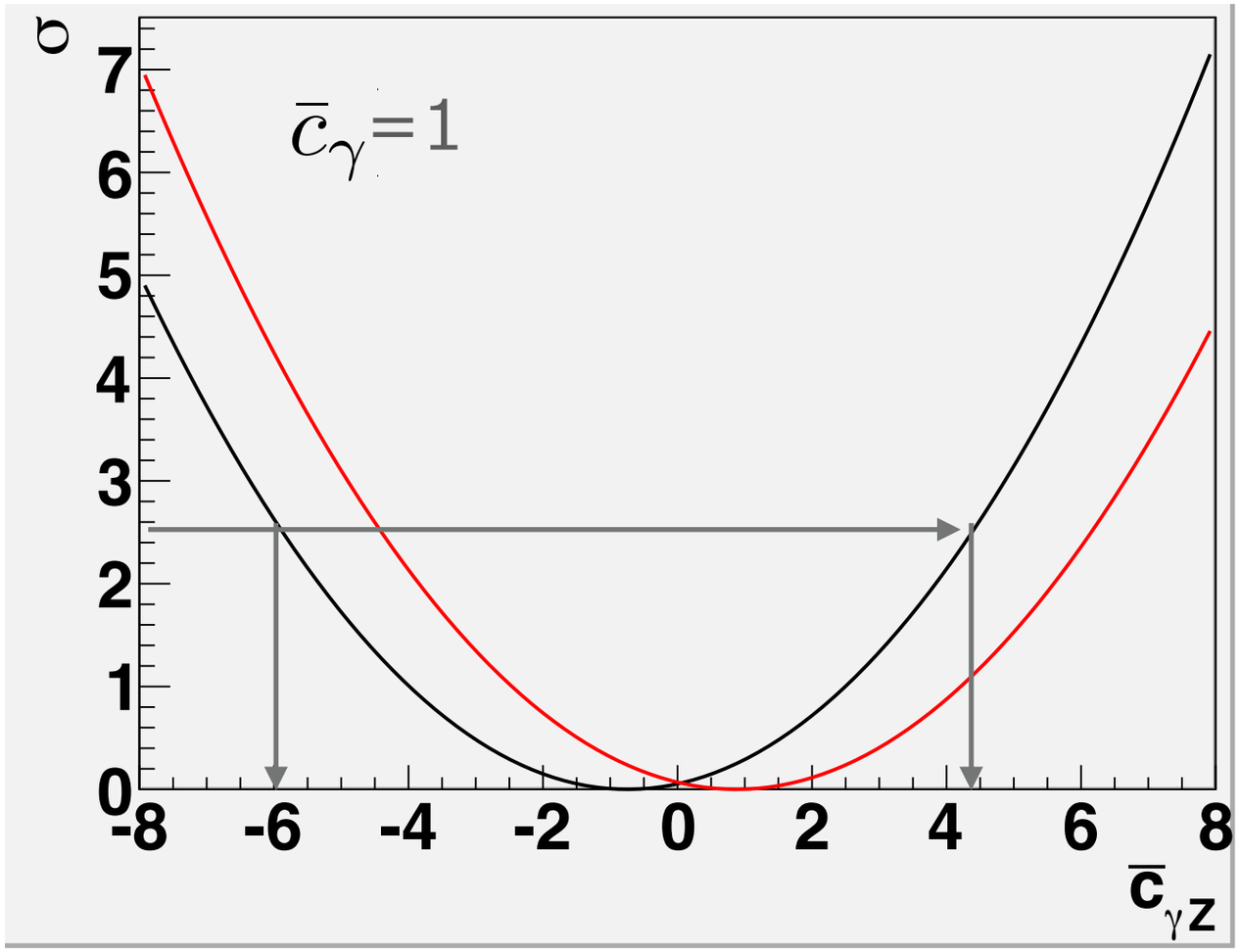
Right handed

$$\frac{\sigma}{\sigma_{SM}} = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_{\gamma})^2$$

If cγZ(bar) change, the cross section change like this graph.

3.Experimental Method (Continued)

Absolute value of the cross section



Left handed $\sigma_{SM} = 0.29[fb]$

$$\sigma_L = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_\gamma)^2\sigma_{SM}$$

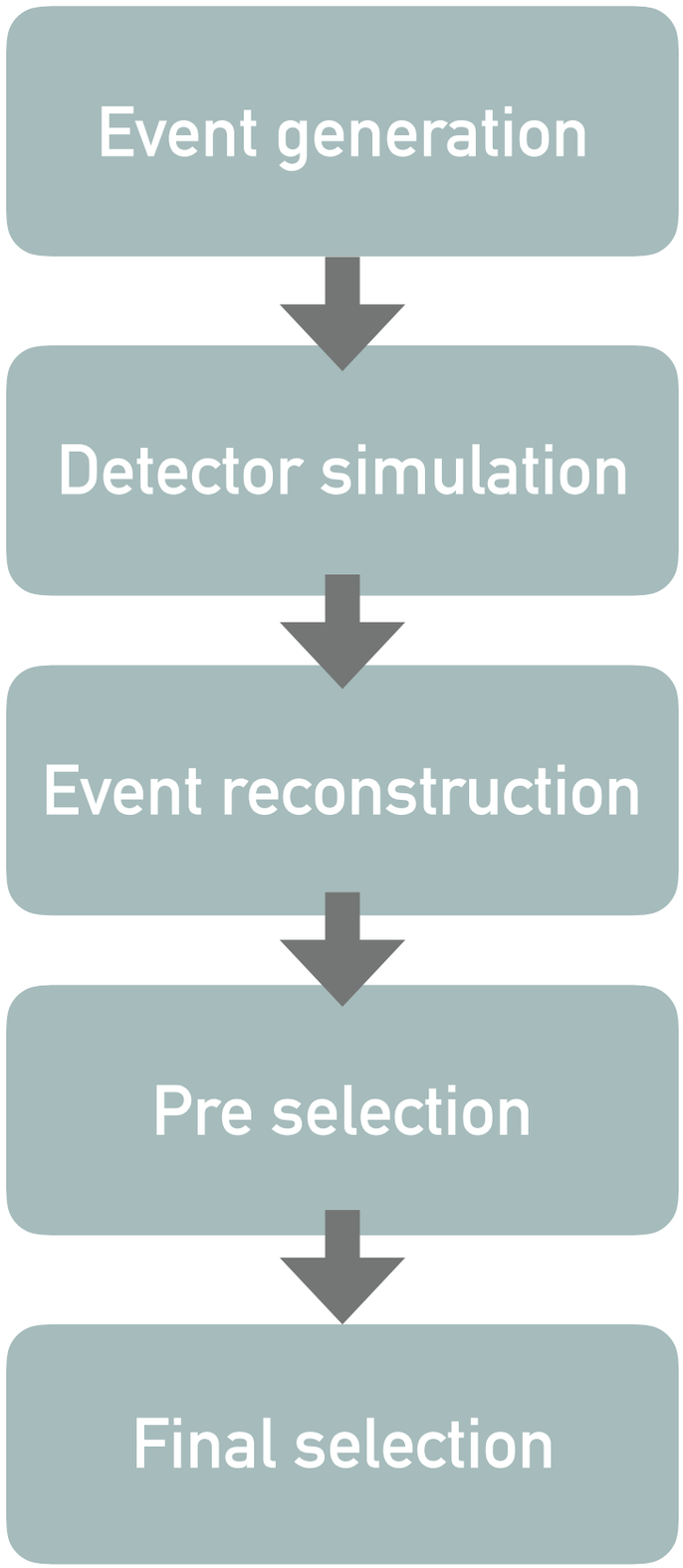
Right handed $\sigma_{SM} = 0.0014[fb]$

$$\sigma_R = (8.01\bar{c}_{\gamma z} - 7.01\bar{c}_\gamma)^2\sigma_{SM}$$

experimental observable : σ

We can get $c_{\gamma z}$ by this formula.

4.Simulation framework



- Physsim
  - √s=250 GeV
  - Integrated Luminosity: 2000 fb^{-1}
  - back ground : DBD sample
- ILD full simulation (Mokka)
- iLCSoft v01-16-02
  MarlinReco, PandoraPFA,
  LCFI+, Isolated photon finder, jet clustering

5. Event selection

Signal: $e^+e^- \rightarrow \gamma H \rightarrow \gamma(b\bar{b})$

Signal signatures

1. Isolated monochromatic photon with energy 93 GeV
2. 2 b jets
3. m(bb) (invariant mass) = higgs mass

Main backgrounds

e+e- ->γqq(bar) dominated by e+e- → γZ (radiative return)

6. Event selection

① Pre-selection

- Isolated photon

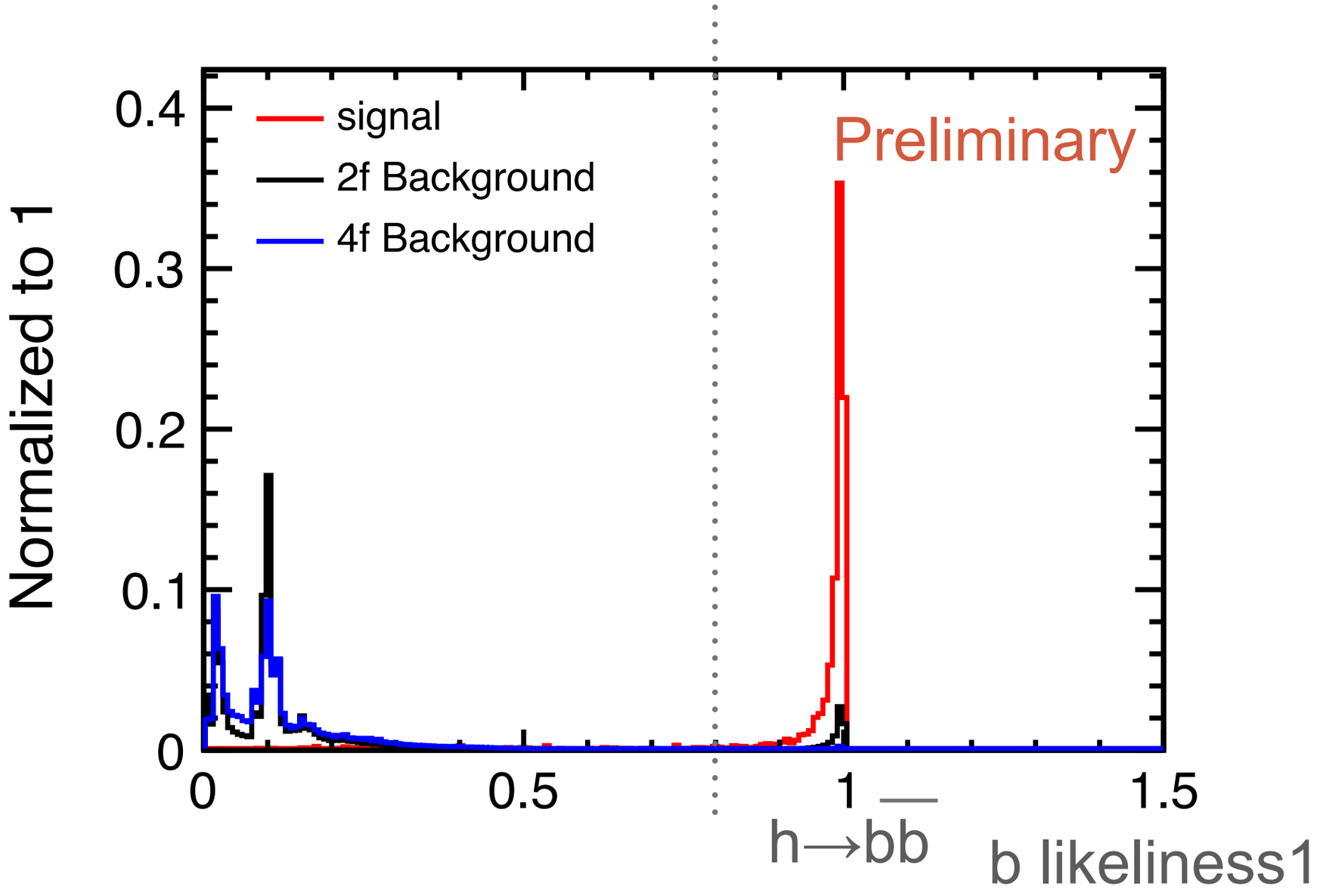
  - ➤ Photon ID
  - ➤ $E_\gamma > 50$ GeV

→Left events except photon

  - ➤ 2jet clustering (Durham)
  - ➤ Flavor tagged（LCFI+）

6. Event selection

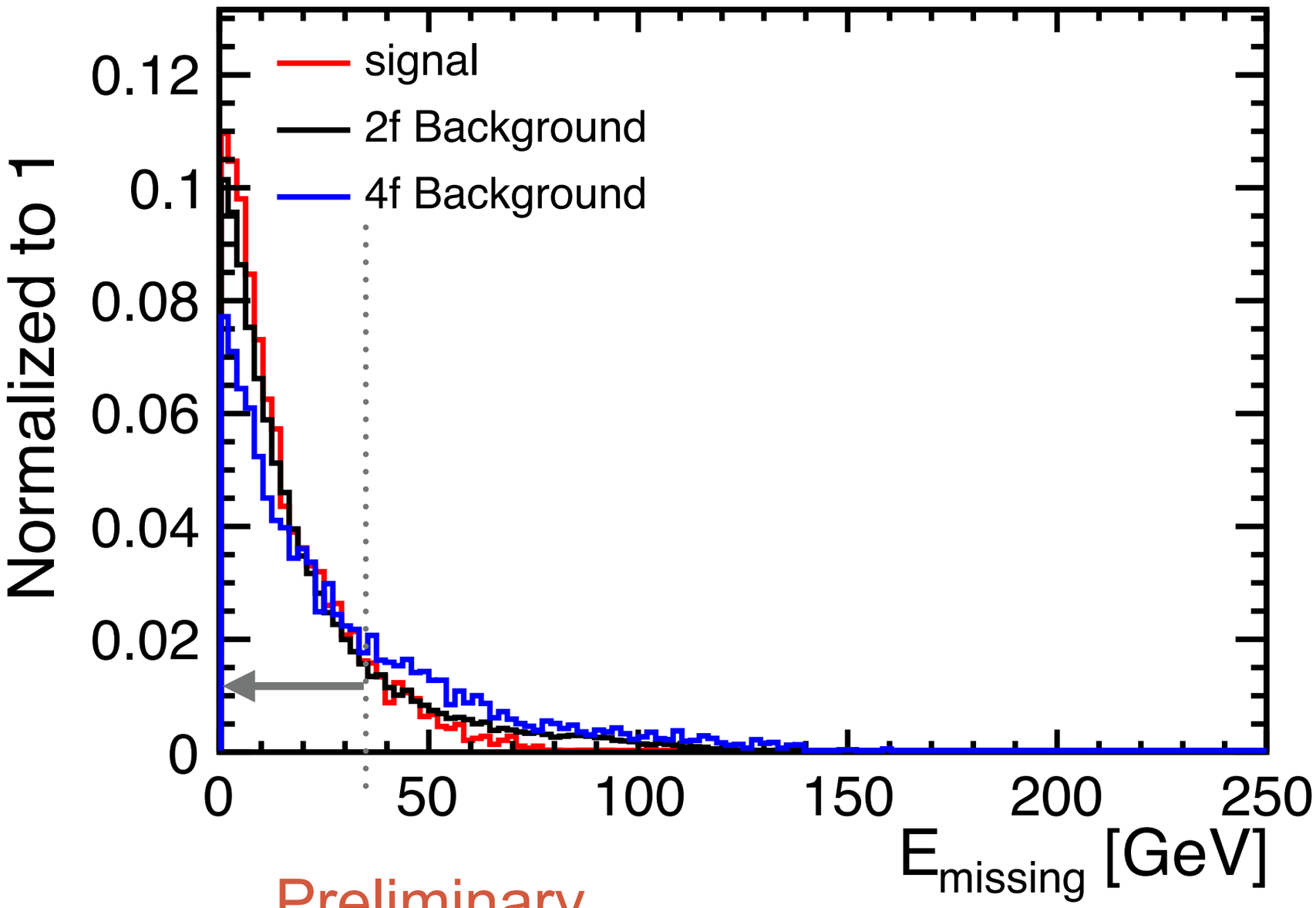
② Final selection
-Cut 1:b likeliness1>0.8 →Suppress light flavor γqq



※ This plot is for events after the pre selection

6. Event selection

② Final selection
-Cut 2: missing energy<35 GeV

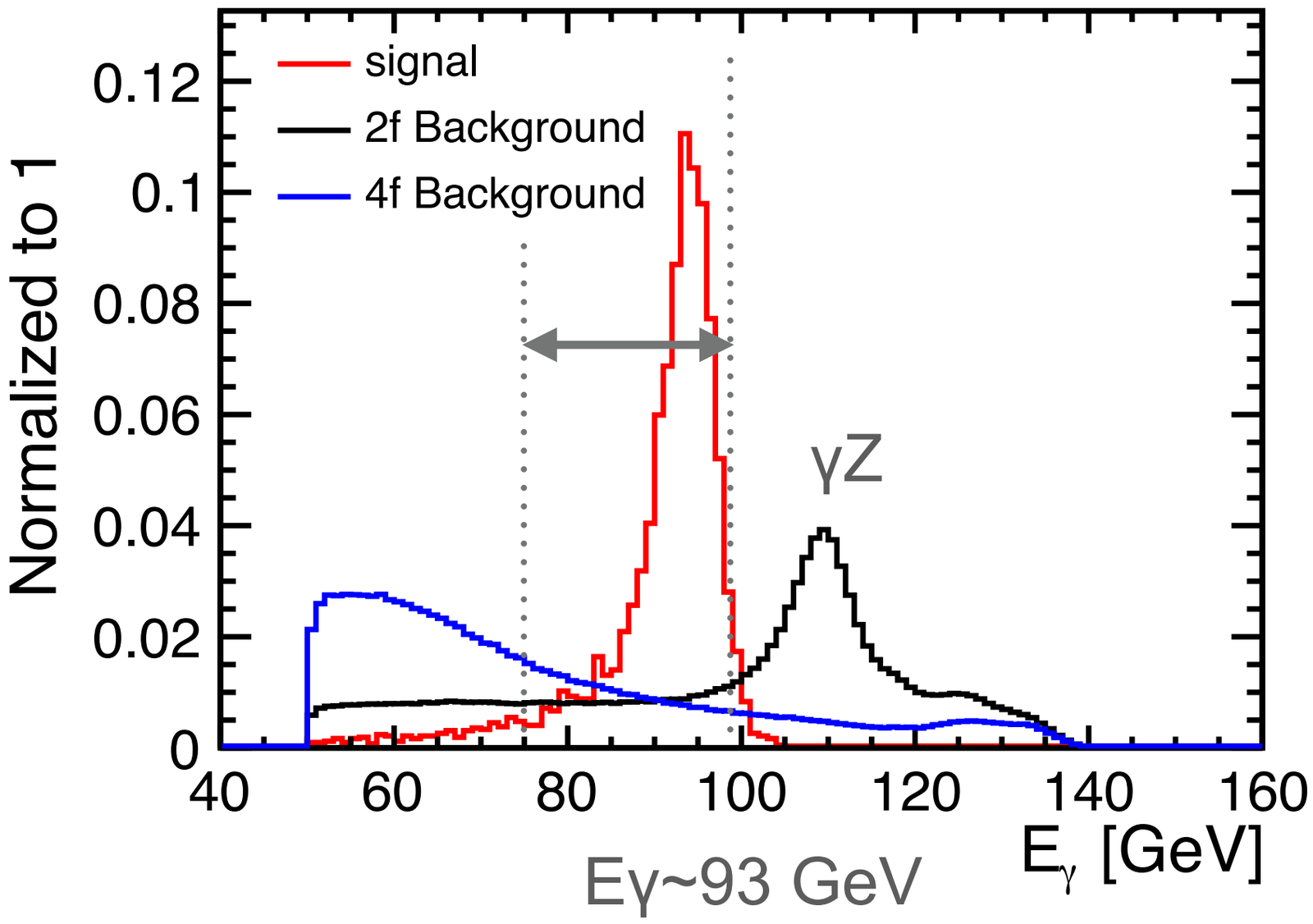


Preliminary

Large missing energy→decay for invisible

6. Event selection

② Final selection
-Cut 3: Photon energy(Eγ) 75 GeV<Eγ<98 GeV

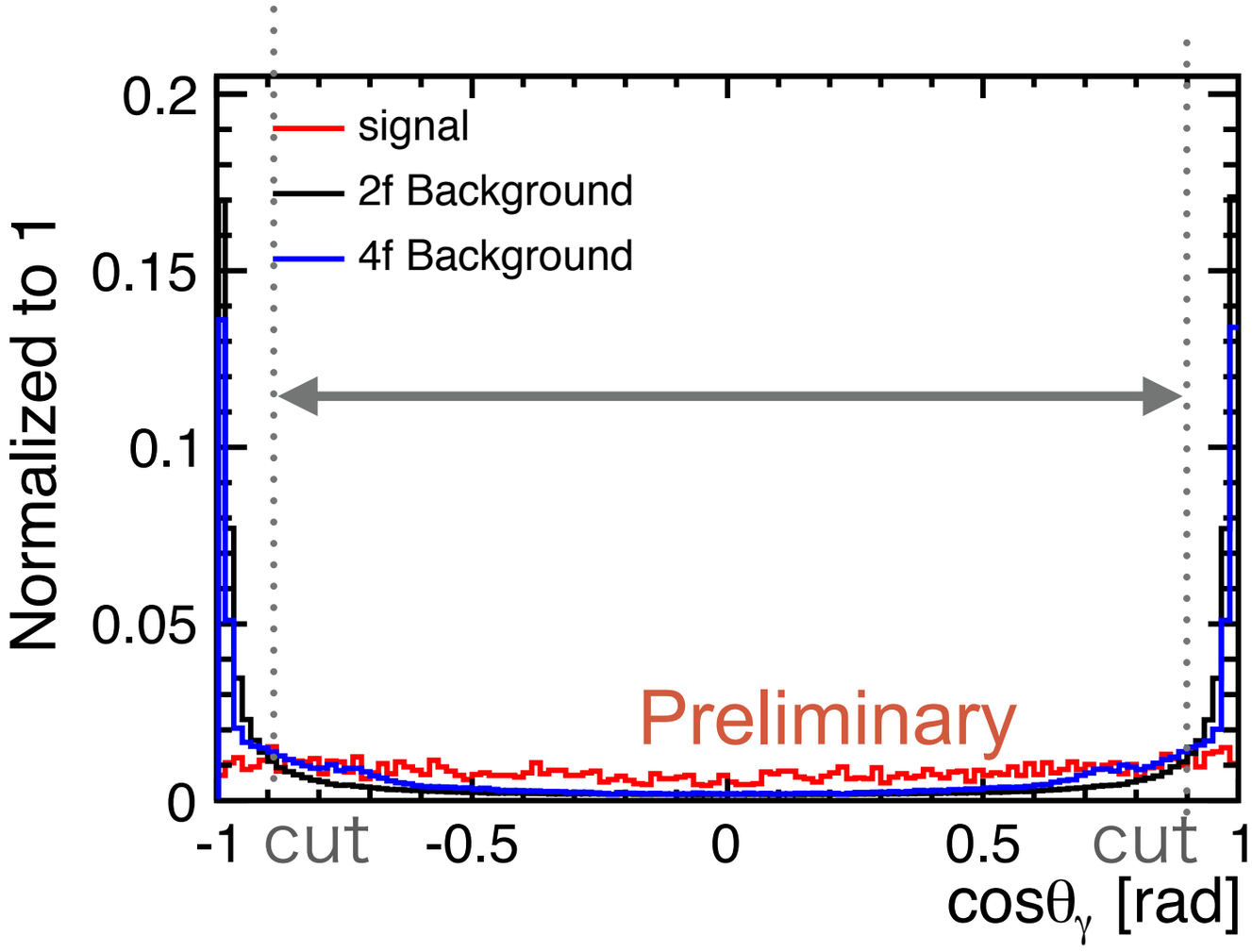


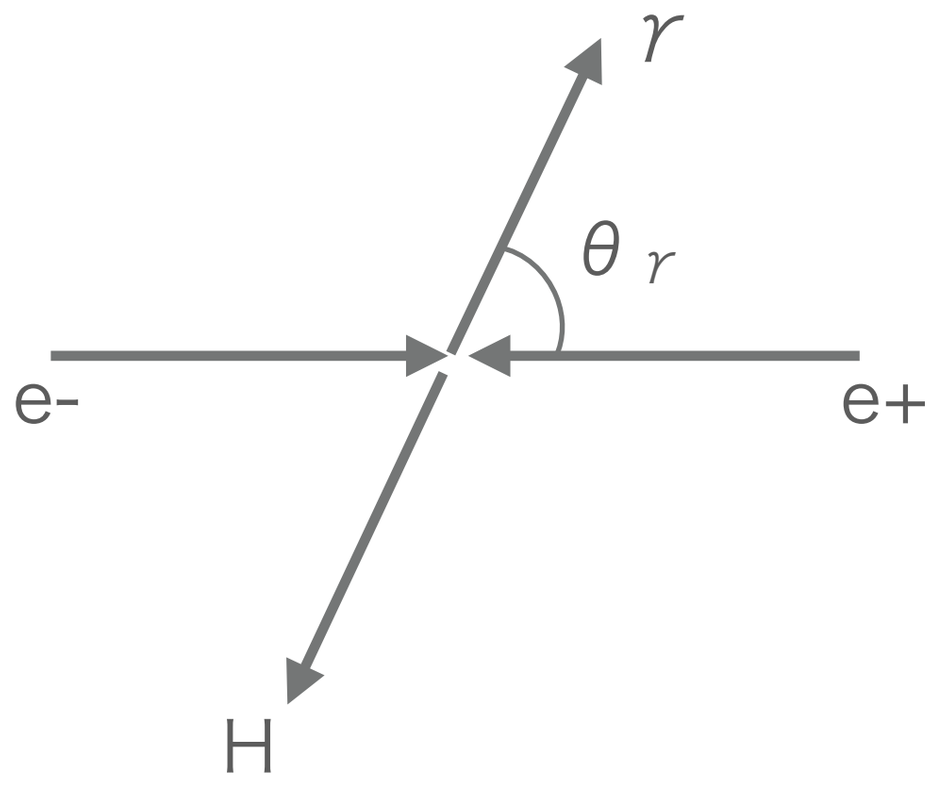
Preliminary

6. Event selection

② Final selection
-Cut 4 : Polar angle of photon

$-0.9<\cos\theta_\gamma<0.9$



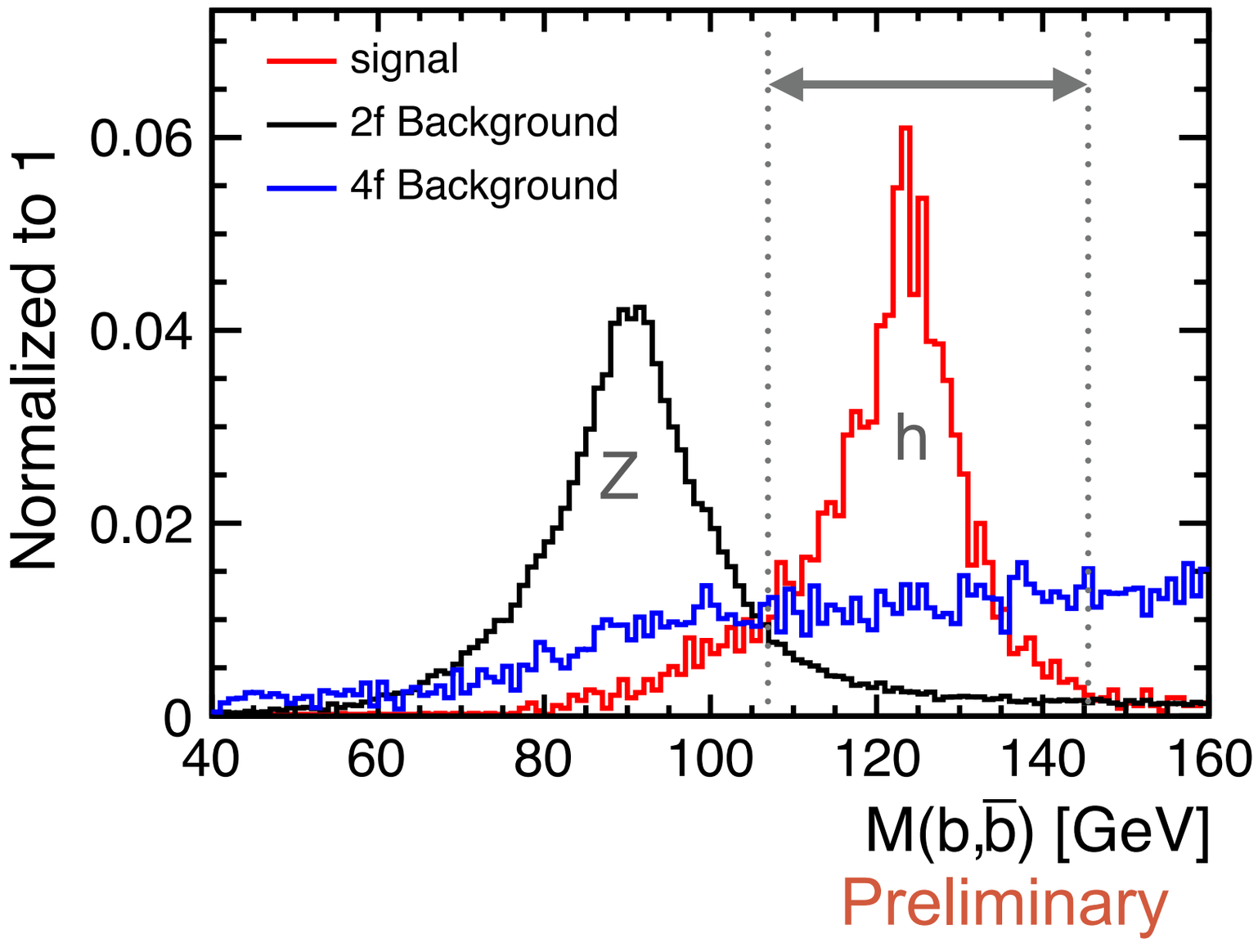


the background have very forward or backward photon

6. Event selection

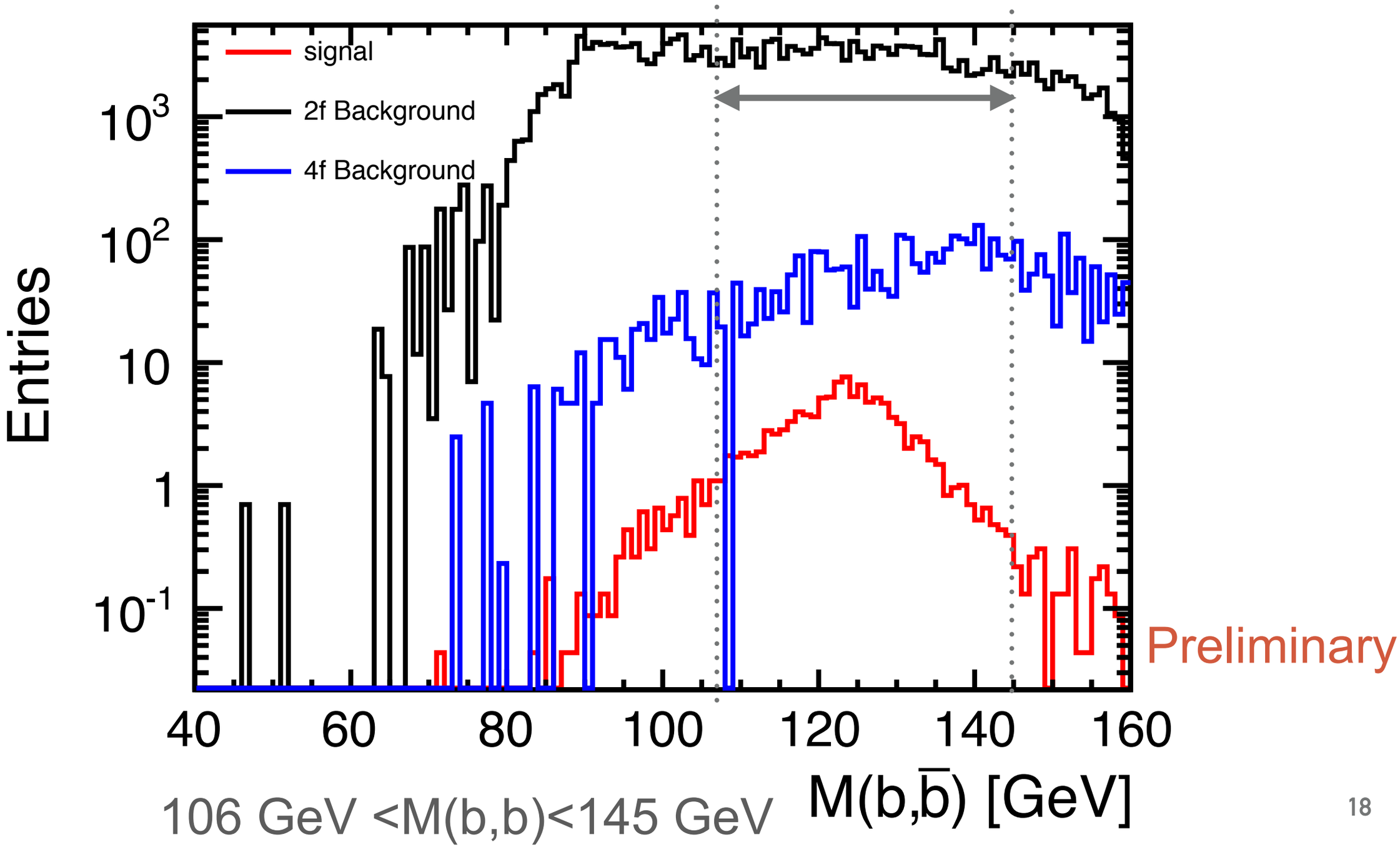
② Final selection
-Cut 5 ：bb invariant mass

106 GeV<M(b,b)<145 GeV



6. Event selection

After all the other cuts, normalized to Integrated Luminosity: 2000 fb^{-1}



106 GeV <M(b,b)<145 GeV

6. Result

$$significance = \frac{N_s}{\sqrt{N_s + N_B}}$$

Reduction table Preliminary

N_s:Number of signal
N_B:Number of back ground

	Signal	background	Significance
Expected	196	314,154,000	0.01
Pre selection	184	68,287,700	0.02
btag>0.8	164	4,914,990	0.07
E_{mis}<35	150	4,268,840	0.07
75<Eγ<98	135	415,621	0.21
-0.9<cosθγ<0.9	126	290,768	0.23
106<M(b,b)<145	108	129,259	0.30

6. Result

→95% C.L upper limit $\sigma = \dfrac{1.64}{significance}\sigma_{SM}$

Significance = 0.30 for SM

= 5.46 × 0.29 [fb]

=1.58 [fb] （Left handed）

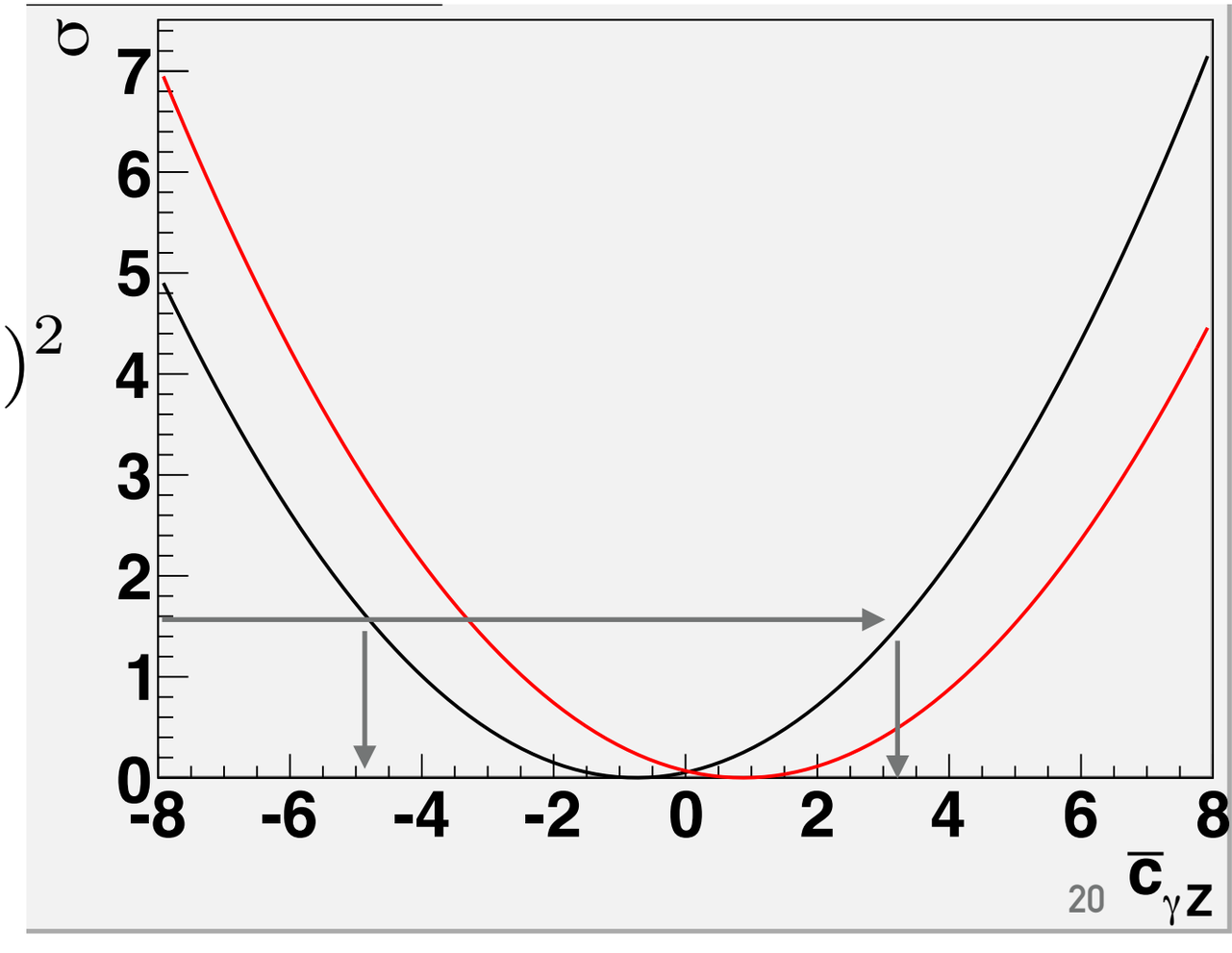
$$\sigma_L = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2\sigma_{SM}$$

$$\frac{\sigma_L}{\sigma_{SM}} = 5.46 = (0.573\bar{c}_{\gamma z} + 0.427\bar{c}_{\gamma})^2$$

-4.82<. $\bar{c}_{\gamma z}$<3.33

$c_{\gamma Z(SM)}$=0.112

-0.54<$c_{\gamma Z}$<0.37 (Λ=1 TeV)



Next approach

h->bb channel

- do analysis for right handed beam polarization
- use Multivariate Data Analysis

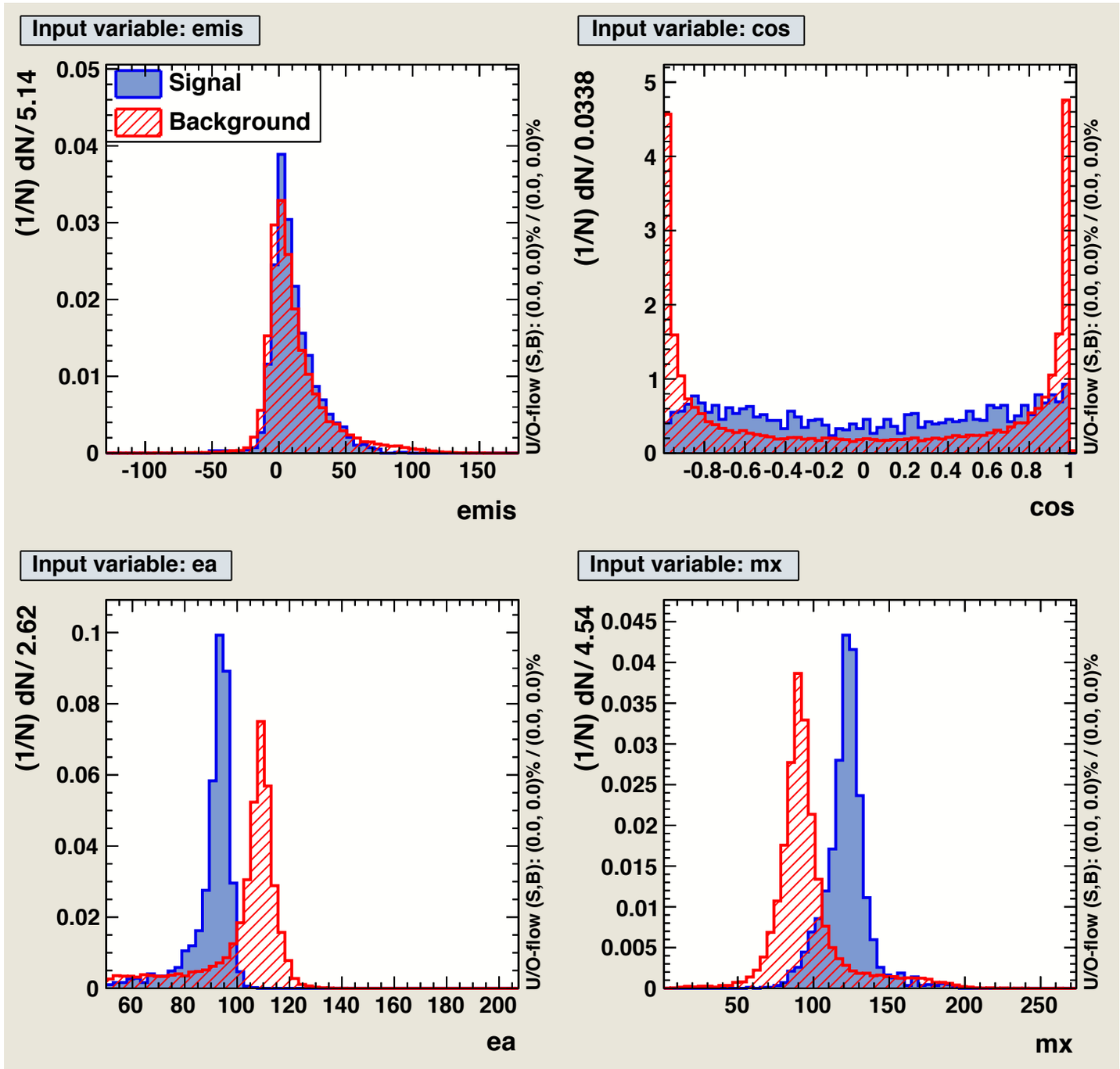
h->WW* channel

Multivariate Data Analysis

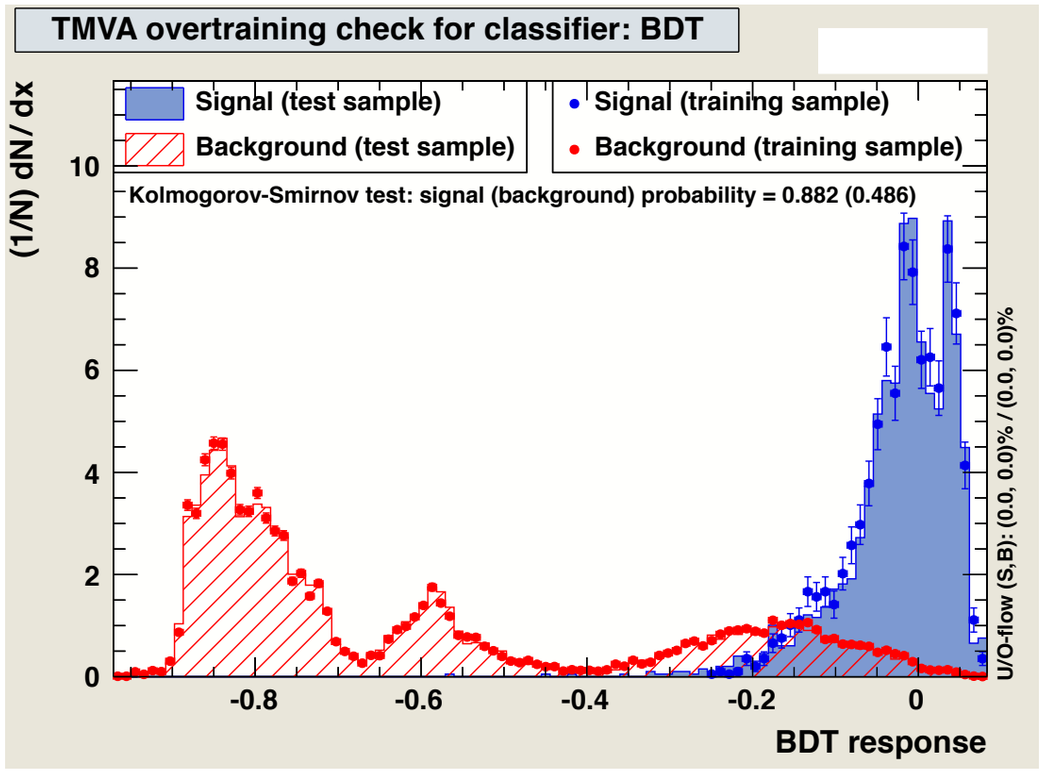
Signal sum of weights:
183.675
Background sum of weights:
6.92861e+07

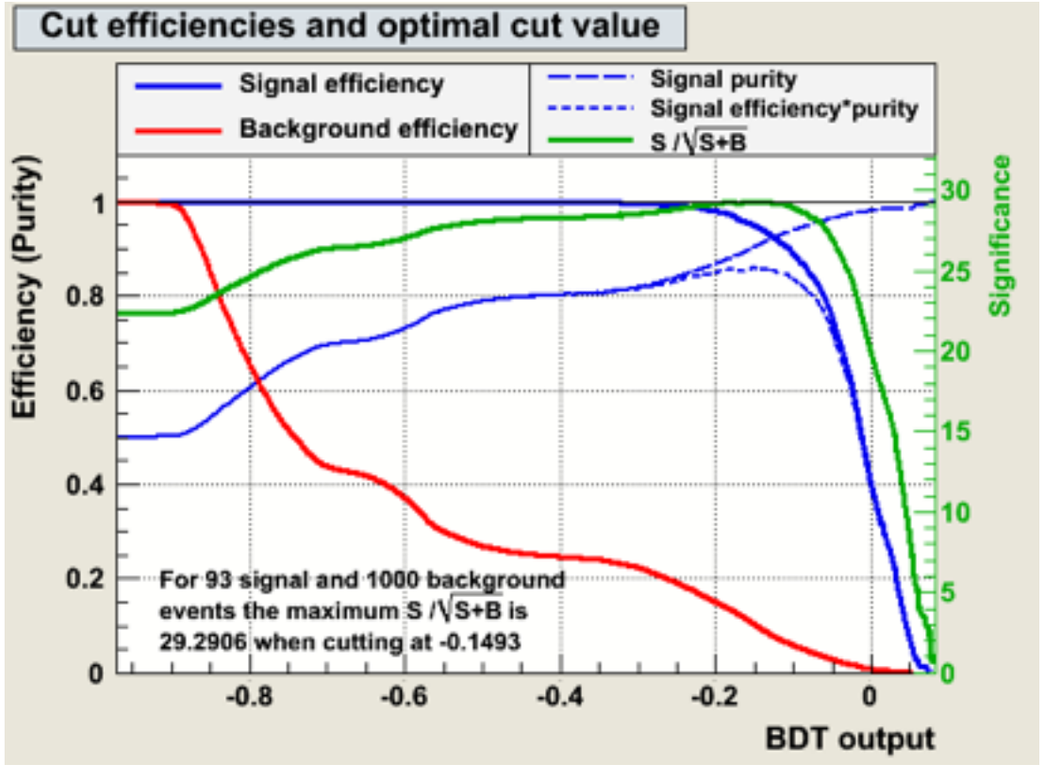
Input parameters

- Missing energy
- Polar angle of photon
- Photon energy
- bb invariant mass



Multivariate Data Analysis

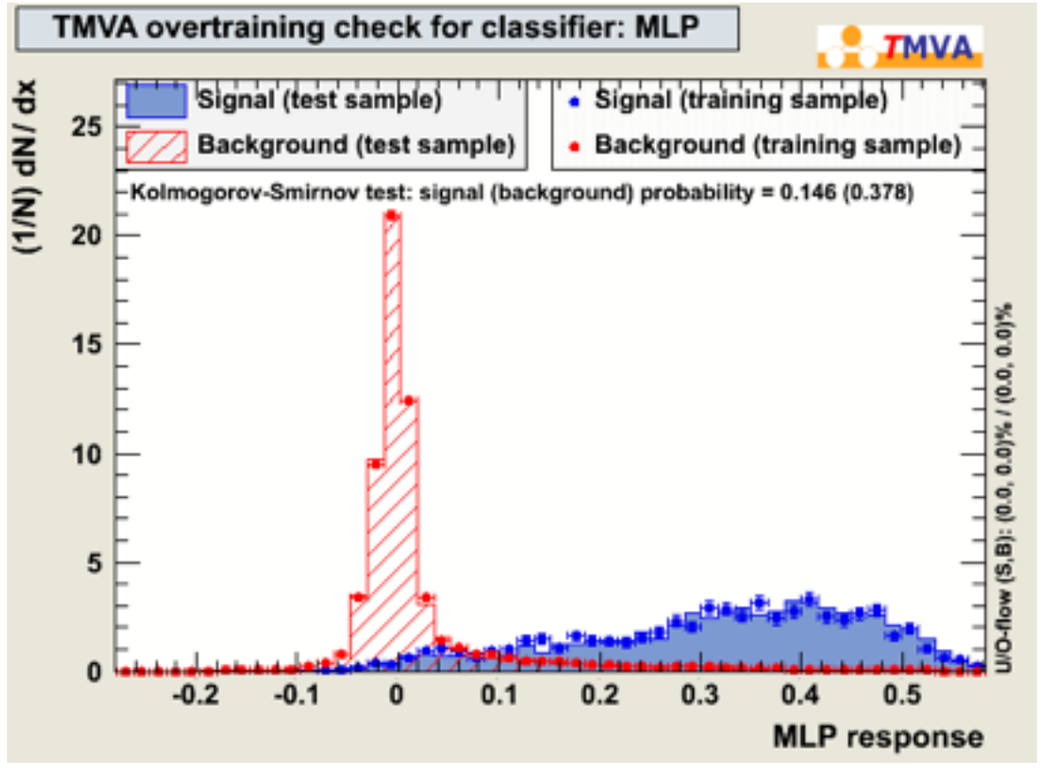


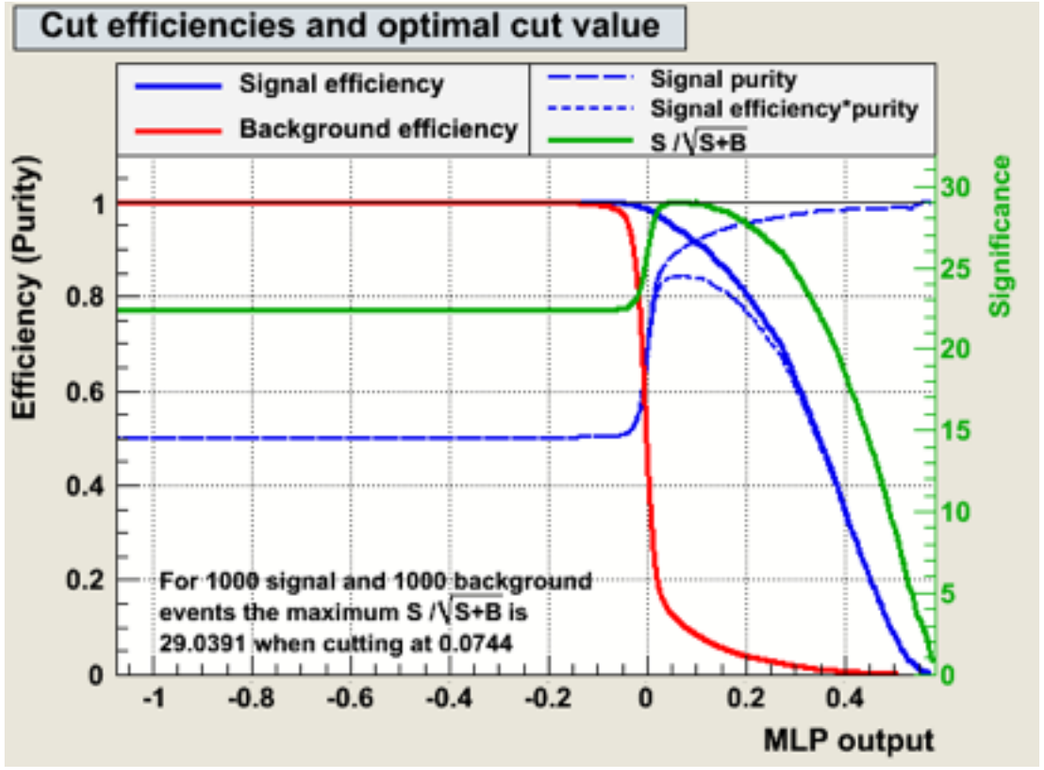


BDT

Significance

= 0.29





MLP

Significance

= 0.29

7. Summary

- I simulated and analyzed e+e- -> h gamma process
- Significance for e+e- ->hγ process

  ~ 0.30σ for SM at $\sqrt{s}$=250 GeV, 2000 fb^{-1}

- model independent upper limit for cross section : $\sigma_{h\gamma}$< 1.6 fb(95% C.L.)
- Corresponding bounds : -4.82<$\bar{c}_{\gamma z}$<3.33

※This is the first look at this process and the results are very preliminary.

Ongoing

- do analysis for right handed beam polarization
- use Multivariate Data Analysis

Next step

- try h->WW* channel
- interpret cγZ bounds based on full 1-loop calculation
- Understand the role of this measurement in one global EFT analysis

Back up

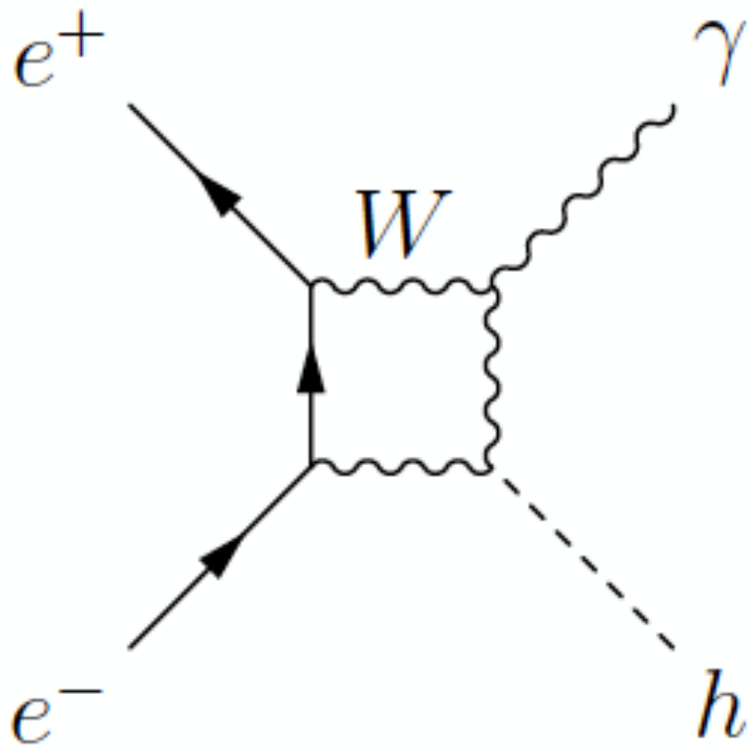
5. Event selection

Back ground

		characteristic	How to remove
f f		back to back	cosθ2f
γZ→γ(f f)	γll	few track number	nTrack
	γqq,γcc	no b	b-tag
	γbb	different angular distribution	Eγ,cosθγ
	common	m(bb)~m(Z)	m(ff)
W^+W^-→4f Z^+Z^-	4j	4 jet	Y3→2, Eγ
	2j+2l	Nisolep=2	N_{isolep}=0, Eγ
	2j+νν	large missing energy	E_{miss},Eγ
	2j+lν	missing energy	N_{isolep}=0, E_{miss}
	common	m(ff)=m(W)	b-tag, m(ff)

l:lepton q:quark j:jet ν:neutrino

About Box diagram



- This diagram is also exist
- We ignore this first, and if calculate of this diagram is finished, we include this.